



National Institute of Standards & Technology

Certificate

Standard Reference Material® 2044

White Diffuser for Spectral Reflectance from 250 nm to 2500 nm

This Standard Reference Material (SRM) is intended for use in calibrating the radiometric scale of spectral reflectometers. SRM 2044 consists of a 5.1 cm diameter by 1 cm thick diffuser prepared from white optical-grade thermoplastic resin that has undergone a sintering process. The diffuser is housed in a protective Delrin container with the diffuser press fitted into the lower half of the container. The container lid was designed so as not to impinge upon the diffuser's certified surface. Certified spectral reflectance values and their uncertainties are listed in Tables 1 and 2, respectively.

Expiration of Certification: This certification is valid until **9 March 2000** within the measurement uncertainties specified, provided the SRM is handled and stored in accordance with the instructions given in this certificate. However, the certification will be nullified if the SRM is altered, contaminated or damaged.

Maintenance of SRM Certification: Control samples from the production lot are retained by NIST and verified on a periodic basis. SRM 2044 may be recertified assuming the surface is unaltered. For recertification, contact P.Y. Barnes of the NIST Optical Technology Division; phone (301) 975-2345; fax (301) 840-8551; email yvonne.barnes@nist.gov.

Instructions for Use: SRM 2044 is to be used to calibrate the radiometric scale of reflectometers using hemispherical geometry. The values certified in the table are for 6°/hemispherical geometry. In this configuration, the measurement direction was 6° from the normal of the diffuser.

Handling and Care: SRM 2044 cannot be cleaned without adversely affecting the certified surface. Therefore, the diffuser must be handled carefully so that the certified surface is not touched or contaminated. Airborne particulates and aromatics as well as breath and fingerprints can contaminate the surface of the diffuser. Face masks and lint-free (nylon or latex) gloves must be worn at all times when handling the SRM. If using a whole glove is not practical, use finger cots or cut the glove and use the finger/thumb sections.

If and only if dust must be removed, be extremely careful and gently use a very clean air bulb and so that no damage is done to the certified surface. When not in use, the diffuser should be stored in its original container.

The diffusers used for this SRM were produced and prepared by Labsphere Inc., North Sutton, NH.

The initial research and development of this SRM were conducted by P.Y. Barnes of the NIST Optical Technology Division.

The overall direction and coordination of the technical measurements leading to certification were performed under the direction of R.D. Saunders of the NIST Optical Technology Division.

The technical and support aspects involved in the certification and issuance of this SRM were coordinated through the Standard Reference Materials Program by R.J. Gettings

Gaithersburg, MD 20899
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Thomas E. Gills, Chief
Standard Reference Materials Program

Table 1. Certified Values for Spectral Diffuse Reflectance of SRM 2044

λ (nm)	Reflectance	λ (nm)	Reflectance	λ (nm)	Reflectance
250	0.970	1150	0.991	2130	0.945
260	0.972	1200	0.990	2140	0.942
270	0.975	1250	0.990	2150	0.946
280	0.978	1300	0.989	2160	0.946
290	0.980	1350	0.988	2170	0.955
300	0.983	1400	0.988	2180	0.960
310	0.986	1450	0.989	2190	0.964
320	0.988	1500	0.989	2200	0.966
330	0.990	1550	0.988	2210	0.966
340	0.991	1600	0.988	2220	0.967
350	0.992	1650	0.987	2230	0.967
360	0.992	1700	0.986	2240	0.966
370	0.993	1750	0.986	2250	0.965
380	0.993	1800	0.985	2260	0.964
390	0.993	1850	0.980	2270	0.964
400	0.993	1900	0.978	2280	0.963
450	0.993	1950	0.978	2290	0.961
500	0.993	2000	0.970	2300	0.960
550	0.993	2010	0.969	2310	0.959
600	0.992	2020	0.966	2320	0.957
650	0.992	2030	0.965	2330	0.956
700	0.992	2040	0.961	2340	0.954
750	0.992	2050	0.959	2350	0.951
800	0.992	2060	0.956	2360	0.951
850	0.992	2070	0.956	2370	0.950
900	0.992	2080	0.952	2380	0.950
950	0.991	2090	0.951	2390	0.949
1000	0.991	2100	0.951	2400	0.947
1050	0.991	2110	0.950	2450	0.946
1100	0.991	2120	0.948	2500	0.945

Table 2. Uncertainties for Certified Spectral Diffuse Reflectance Values

Uncertainty Type	Wavelength
	250 nm - 2500 nm
Type A Uncertainty	0.0014
Type B Uncertainty	0.0015
Combined Uncertainty	0.0021
Expanded Uncertainty ($k = 2$)	0.004

Determination of Certified Spectral Reflectance: Batch certification was accomplished by measurement on the NIST High Accuracy Reference Reflectometer-Spectrophotometer [1,2], and a high precision primary standard transfer spectrophotometer (Perkin-Elmer Lambda-19). Measurements were made as a function of wavelength (See Figure 1).

The reference reflectometer uses a xenon arc as the source and a silicon photodiode as the detector over the spectral range of 250 nm through 400 nm, and a quartz tungsten-halogen lamp as the source and a silicon photodiode as the detector over the spectral range of 450 nm to 1100 nm. An Oriel Multispec¹ (Model Number 257) monochromator was used to limit and select the spectral pass band of the incident radiation. The collimated incident beam was 20 mm in diameter and the spectral pass band was 10 nm. A primary standard transfer spectrophotometer Perkin Elmer Lambda-19 was used to certify SRM 2044 over the spectral range of 1100 nm through 2500 nm. The Lambda-19 uses a quartz tungsten halogen lamp as the source and a lead sulfide photoconductor as the detector. The spectral pass band varied between 3 nm and 20 nm over the spectral region. SRM 2044 was calibrated at selected wavelengths in intervals as follows: 10 nm intervals over the spectral wavelength range from 250 nm to 400 nm, 50 nm intervals over the spectral wavelength range from 400 nm to 2000 nm, 10 nm intervals over the spectral wavelength range from 2000 nm to 2400 nm, 2450 nm and 2500 nm. The certified diffuse reflectance values reported in Table 1 are valid for the condition of illumination in which the incident sample beam is 6 degrees from the normal to the plane of the diffuser's surface.

The laboratory environment was maintained at a temperature of approximately $20\text{ }^{\circ}\text{C} \pm 0.6\text{ }^{\circ}\text{C}$ with a relative humidity of $40\% \pm 0.6\%$.

Determination of Uncertainty of the Certified Values: The expanded uncertainty of the certified values is listed in Table 2 [3,4]. The combined uncertainty was calculated by root-sum-square of the Type A and Type B uncertainties. The expanded uncertainty was calculated using the combined uncertainty with a coverage factor (k) of 2 [5, 7]. Included in the evaluation of the Type A uncertainties are the spatial uniformity over an area 30 mm in diameter, repeat measurement at the same location, and the random noise in the measurement. The contributors to the Type B uncertainty are the receiver system non-linearity and non-uniformity, and stability over the calibration interval.

Reflectance Uniformity: The reflectance uniformity of SRM 2044 was established over an area 30 mm in diameter. The Type A uncertainty ($k = 2$) for these measurements was 0.001.

REFERENCES

- [1] Diffuse Reflectance Coatings and Materials Section, Labsphere Catalog, (1996).
- [2] Bruegge, C.J., Stiegman, A.E., Hale, R.R., Diner, D.J., and Springsteen, A.W., Reflectance Stability, *Analysis of Spectralon Diffuse Calibration Panels*; SPIE 1493, pp. 132-142, (1991).
- [3] Dupont PP & R Department Product Sheets, "Teflon' 7A", "Teflon' 7C", "Teflon' 8", "Teflon' 8A," Granular TFE-Fluorocarbon Resins.
- [4] Proctor, J.E. and Barnes, P.Y., "NIST High Accuracy Reference Reflectometer," J.R. Natl. Inst. Stand. and Tech., Vol. 101, pp. 619-627, (1996).
- [5] Taylor, B.N., and Kuyatt, C.E., "Guidelines for Evaluating and Expressing the Uncertainty of the NIST Measurement Results," NIST Technical Note 1297, U.S. Government Printing Office, Washington DC, (1994).
- [6] Taylor, B.N., "Guidelines for the Use of the International System of Units (SI)," NIST Special Publication 811, 1995 Ed., (April 1995).
- [7] Barnes, P.Y., Early, E.A., and Parr, A.C., NIST Special Publication 250-48, NIST Measurement Services: Spectral Reflectance (1998).

It is the responsibility of users of this SRM to assure that the certificate in their possession is current. This can be accomplished by contacting the SRM Program at: Phone (301) 975-6776 (select "Certificates"), Fax (301) 926-4751, e-mail srminfo@nist.gov, or via the Internet <http://ts.nist.gov/srm>.

¹ Certain Commercial materials and equipment are identified to adequately specify the experiment procedure. Such Identification does not imply a recommendation or endorsement by the National Institute of Standards and Technology, nor does it imply that the materials or equipment are necessarily the best available for the purpose.

Figure 1. Hemispherical Reflectance Factor

